Estimating remaining lifetime of humanity

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Abstract

In this paper, we estimate the remaining time for human existence, applying the Doomsday argument and the Strong Self-Sampling Assumption to the reference class consisting of all members of the Homo sapiens, formulating calculations in traditional demographic terms of population and time, using the theory of parameter estimation and available paleodemographic data. The remaining lifetime estimate is found to be 170 years, and the probability of extinction in the coming year is estimated as 0.43%.

1. Introduction

Modern humans, Homo sapiens, exist according to available data for at least 130,000 years [4], [5]. It is interesting, however, to estimate the time remaining for the survival of humanity.
To determine this value there was proposed the so-called doomsday argument [1] - probabilistic reasoning that predicts the future of the human species, given only an estimate of the total number of humans born so far. This method was first proposed by Brandon Carter in 1983 [2]. Nick Bostrom modified the method by formulating the Strong Self-Sampling Assumption (**SSSA**): each observer-moment should reason as if it were randomly selected from the class of all observer-moments in its reference class. [3].

In this paper, we apply the SSSA method to the reference class consisting of all members of our species, formulating calculations in traditional demographic terms of population and time, using the parameter estimation theory and the available paleodemographic data.

To estimate the remaining time t we will fulfill the assumption that the observer has an equal chance to be anyone at any time. Of course the assumption is a philosophical and somewhat metaphysical. Religious people would have formulated it as "the soul has an equal chance to be in this or that body." However, at least this assumption is simple, symmetrical and devoid of any self-centeredness.

The demographic history of mankind can be shown on a graph (Fig. 1), that has the time x on the horizontal axis and the population $y = h(x)$ on the vertical axis. The initial moment of history denoted a, and the end, that is the time of the disappearance or death of humanity, denoted b. The present moment, that is the moment of observation, denoted x_o - sometimes, however, we will simply denote it x.

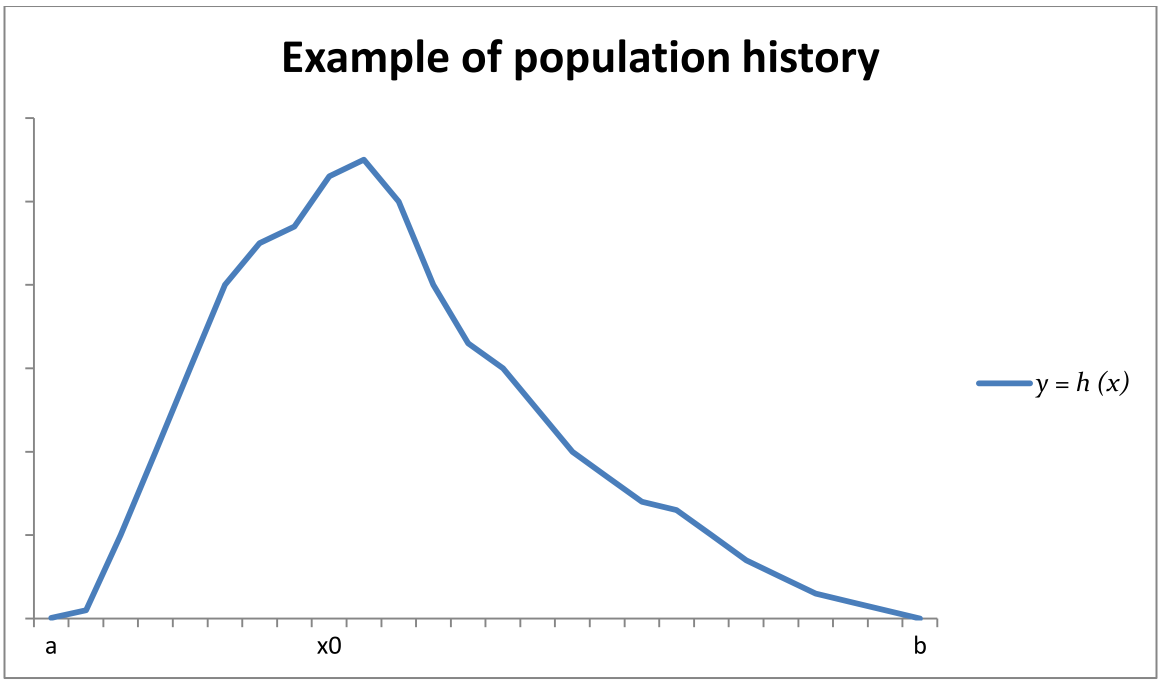

Fig. 1.

Let

$$f(x) = p\,(x_o = x \mid \boldsymbol{h}),$$

where *p* - the conditional probability density of observation moment for a given function *h*. Let $F(x)$ the related distribution function:

$$F(x) = \int_a^x f(\tau)\, d\tau,$$

$H(x)$ is the integral function of passed person-years

$$H(x) = \int_a^x h(\tau)\, d\tau$$

and S is the total number of person-years during the existence of mankind

$$S = H(b).$$

From our assumption, we get:

$$f(x) = h(x) / S \qquad (1)$$

and

$$F(x) = H(x) / S. \qquad (2)$$

2. The proposed estimator

The left side of the graph 1, that is, values $h(x)$ on the interval $[a,x_o]$, is an observation dependent on S. It is proposed the following estimate of the parameter S:

$$\hat{S} = 2H(x), \quad (3)$$

where x - the time of the observation.

Statement 1.

Estimator $\hat{S}$ (3) is unbiased estimator of the parameter S.

Proof.

For each $S > 0$

$$\mathrm{E}[\hat{S}] = 2\mathrm{E}[H(x)].$$

Considering (1),

$\mathrm{E}[\hat{S}] = 2\int_a^b f(x)H(x)dx = \frac{2}{S}\int_a^b H(x)h(x)dx.$

By changing the variable of integration u=$h(x)$, we get

$\mathrm{E}[\hat{S}] = \frac{2}{S}\int_0^S u\, du = \frac{2}{S}\frac{u^2}{2}\Big|_0^S = S.$

Lemma.

$P(\hat{S} < kS) = \frac{k}{2}$, for each $k \in [0,2]$. (4)

Proof.

Considering (2),

$P[\hat{S} < kS]$ = $P[\, 2H(x) < kS\,]$ = $P[\, 2F(x)S < kS\,]$ = $P[F(x) < \frac{k}{2}] = \frac{k}{2}$, (3)

for an obvious property of the distribution function.

Statement 2.

$\hat{S}$ is an median-unbiased estimator of the parameter of S.

Proof.

This follows from Lemma at k = 1.

We compute the mean absolute deviation d of estimate $\widehat{S}$:

$d = \int_a^b |\hat{S} - S| f(x)\, dx = \int_a^b |2H(x) - S| f(x)\, dx = S \int_a^b |2F(x) - 1| f(x)\, dx.$

Substituting $u=f(x)$, we get:

$d = S \int_0^1 |2u - 1|\, du = S \left[-\int_0^{\frac{1}{2}} (2\mathrm{u} - 1)\, du + \int_{\frac{1}{2}}^1 (2\mathrm{u} - 1)\, du \right] =$

$= S\, [\, -u^2|_0^{1/2} + u|_0^{1/2} + u^2|_{1/2}^1 - u|_{1/2}^1] = S\, (-\frac{1}{4} + 1 - \frac{1}{4}) = \frac{\mathrm{S}}{2}.$

We calculate the variance D and the standard deviation σ of estimate $\hat{S}$:

$D = \int_a^b (\hat{S} - S)^2 f(x)\, dx = \int_a^b (2H(x) - S)^2 f(x) dx =$

$= \mathrm{S}^2 \int_a^b (2F(x) - 1)^2 f(x) dx.$

Substituting $u=f(x)$, we get:

$D = S^2 \int_0^1 (2u - 1)^2\, du = S^2 \left[\int_0^1 4\mathrm{u}^2\, du - \int_0^1 4u du + \int_0^1 du \right] =$

$= S^2\, [\, \frac{4}{3} u^3|_0^1 - 2u^2|_0^1 + \mathrm{u}|_0^1] = S^2\, (\frac{4}{3} - 2 + 1) = \frac{S^2}{3},$

$\sigma = \frac{S}{\sqrt{3}}.$

Now, on the basis of the estimate of S we can estimate the value of

$R = \int_x^b h(t) dt = S - H(x)$ (5)

as

$\hat{R} = \hat{S} - H(x) = 2H(x) - H(x) = H(x)$. (6)

3. Applying to the historic data

Let apply (6) to our particular historical situation where x = 2015 (year). Historical population data is taken from [4]. According to [5] at the time that the species Homo Sapiens originated, between 130,000 and 190,000 years ago, its population was between 120,000 to 325,000 people. We will take the middle points of these ranges: a = -158000, $h\ (a)$ = 222500. Population data between -10000 and 2000 is taken from [4], [6], and after the year 2000 from [4], [7]. The used data are shown in Table 1 and Fig. 2.

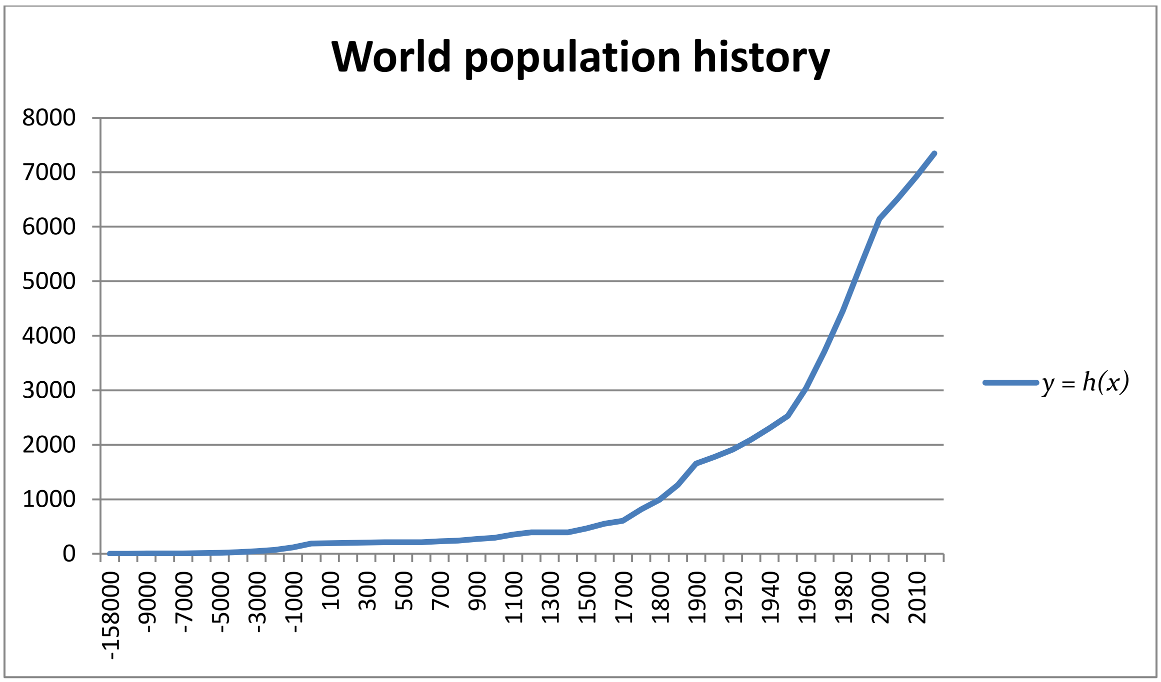

Fig. 2.

x	h, Mil	x	h, Mil
-158000	0.2	1200	393
-10000	2	1300	392
-9000	4	1400	390
-8000	5	1500	461
-7000	8	1600	554

-6000	11	1700	603
-5000	18	1750	814
-4000	28	1800	989
-3000	45	1850	1263
-2000	72	1900	1654
-1000	115	1910	1777
0	188	1920	1912
100	195	1930	2092
200	202	1940	2307
300	205	1950	2528
400	209	1960	3042
500	210	1970	3710
600	213	1980	4461
700	226	1990	5308
800	240	2000	6145
900	269	2005	6514
1000	295	2010	6916
1100	353	2015	7349

Table 1.

Using these data as points for the trapezoidal rule, we obtain

$$H(2015) \approx 1.7 \cdot 10^{12} \text{ (person-years)},$$

and consequently, according to (6) the same estimate for the remaining number of person-years:

$$\hat{R} = 1.7 \cdot 10^{12}. \qquad (7)$$

We now turn to estimate the remaining time of human existence, that is the value $t = b - x_0$, where $x_0 =$ 2015.

We use prediction from [8] (see. Fig. 3):

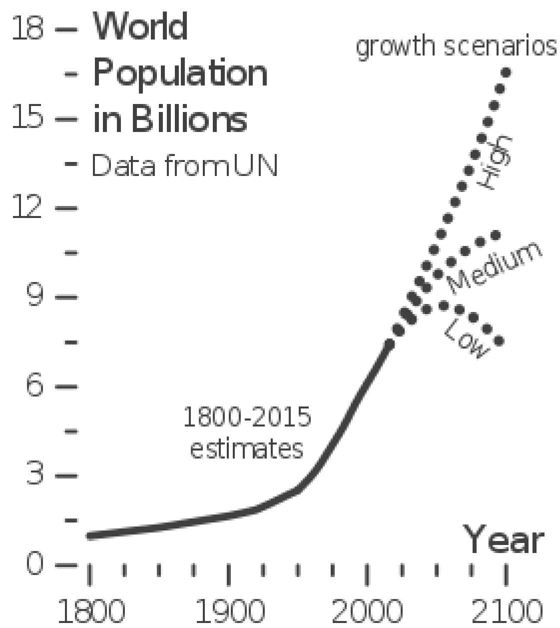

Fig. 3

As you can see, the average prediction for 2100 exceeds 11 billion, but the growth is slowing down, and then you can expect stabilization or even decrease in the number. Therefore, we take as characteristic number for the period x > 2015 value

$$\hat{h} = 10^{10} \quad (8)$$

and using (7) we obtain an estimate of the remaining time t as

$$\hat{t} = \frac{\hat{R}}{\hat{h}} = \frac{1.7 \cdot 10^{12}}{10^{10}} = 170 \quad (9)$$

and an estimate of the last year of human existence b is

$$\hat{b} = x_0 + \hat{t} = 2015 + 170 = 2185.$$

But it is, of course, only a medium estimate. Designating $L = H(x_0)$ и considering (3), (5) и (6), we get from (4):

$$\frac{k}{2} = P[\hat{S} < kS] = P[2L < k(L+R)] = P[2L < kL + kR] =$$

$$= P\,[\,(2\text{-}k)L < kR\,] = P[\frac{R}{L} > \frac{2-k}{k}].$$

Substituting $q = \frac{2-k}{k},\ k = \frac{2}{q+1}$ we obtain

$$P\left(\frac{R}{L} > q\right) = \frac{1}{q+1}$$

for q >= 0.

Assuming h is constant for $x > x_0$ we get

$$P\left(\frac{t\hat{h}}{L} > q\right) = \frac{1}{q+1}.$$

Substituting $z = Lq/\hat{h}$, we get

$$P(t > z) = \frac{1}{\frac{z\hat{h}}{L}+1} = \frac{1}{\frac{z}{\hat{t}}+1} \quad (10)$$

The following chart shows the probability of mankind to survive a certain number of years for the value $\hat{t}$ from (9).

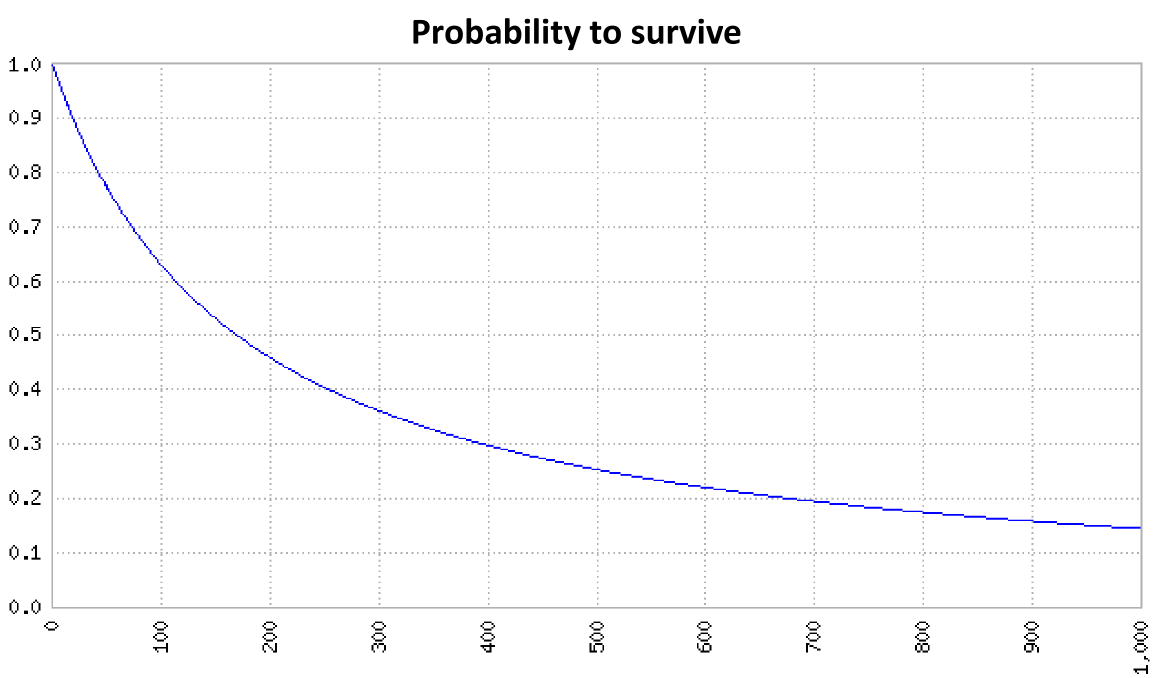

Fig. 4

We now calculate more accurately the probability to exist one next year. Let $\hat{h} = 7.4 \cdot 10^9$, according to the data for 2016 year from [7]. Then

$$\frac{L}{\hat{h}} = \frac{1.7 \cdot 10^{12}}{7.4 \cdot 10^9} = 230,$$

and from (10) we get

$$P(t > 1) = \frac{1}{\frac{1}{230}+1} = 0.99567$$

and the opposite probability of extinction

$$P(t \leq 1) = 0.00433 = 0.43\%. \qquad (11)$$

4. Discussion

The result (9), if we consider it typical for other intelligent beings in the universe, can explain the famous Fermi Paradox [9]. According to our experience at the time x_0 civilization is practically not observable on a cosmic scale, and after t = 170 years is disappeared.
Our estimates are in good agreement with the real threats to the existence of mankind, chief among which is the nuclear weapons. It follows from (11) that the estimate of the probability of nuclear war remarkably coincides with the data of [10] obtained by a public survey - 2% over 5 years, i. e. 0.4% per year.
However, take into account that we really estimated only the integral amount of $R \sim ht$, and the value t itself was received with the assumption of the future stabilization of h. Therefore, humanity can extend the lifetime t, reducing its numbers h by further reducing birth rate. Related improvement of quality of life and population ageing will reduce aggressivity and therefore the likelihood of war. This conclusion is consistent with the conclusions of the Malthusian school [11].
Governments and international financial and economic organizations should recognize the new reality. Inevitable with decreasing and aging of the population reduction and even cessation of economic growth is a good which will extend the existence of our civilization.

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